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Nishiyama et al.

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(54) **INKJET PRINTING APPARATUS**

(71) Applicant: **RISO KAGAKU CORPORATION**, Tokyo (JP)

(72) Inventors: **Akira Nishiyama**, Ibaraki (JP); **Hiroshi Sugitani**, Ibaraki (JP)

(73) Assignee: **RISO KAGAKU CORPORATION**, Tokyo (JP)

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(51) **Int. Cl.**
B41J 2/175 (2006.01)

(52) **U.S. Cl.**
CPC ***B41J 2/17596*** (2013.01)

(58) **Field of Classification Search**
CPC B41J 2/175; B41J 2/18; B41J 2/17596
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,082,851	A *	7/2000	Shihoh	B41J 2/175 347/85
6,386,689	B1 *	5/2002	Sasada	347/85
8,794,747	B2 *	8/2014	Enomoto et al.	347/85
2008/0024553	A1 *	1/2008	Morgan	B41J 2/1707 347/42
2008/0151014	A1 *	6/2008	Matsuda	B41J 2/17596 347/85
2008/0158307	A1	7/2008	Nitta et al.	
2010/0177148	A1 *	7/2010	Asami	B41J 2/175 347/85
2010/0247769	A1 *	9/2010	Ooishi	B41J 2/175 427/256
2012/0299989	A1 *	11/2012	Prothon et al.	347/6
2014/0043381	A1 *	2/2014	Izawa	B41J 2/17596 347/6

FOREIGN PATENT DOCUMENTS

JP 2008-162262 7/2008

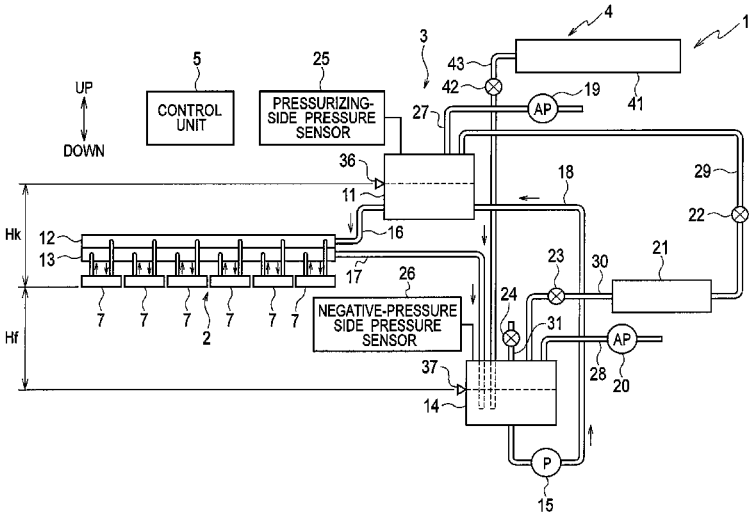
* cited by examiner

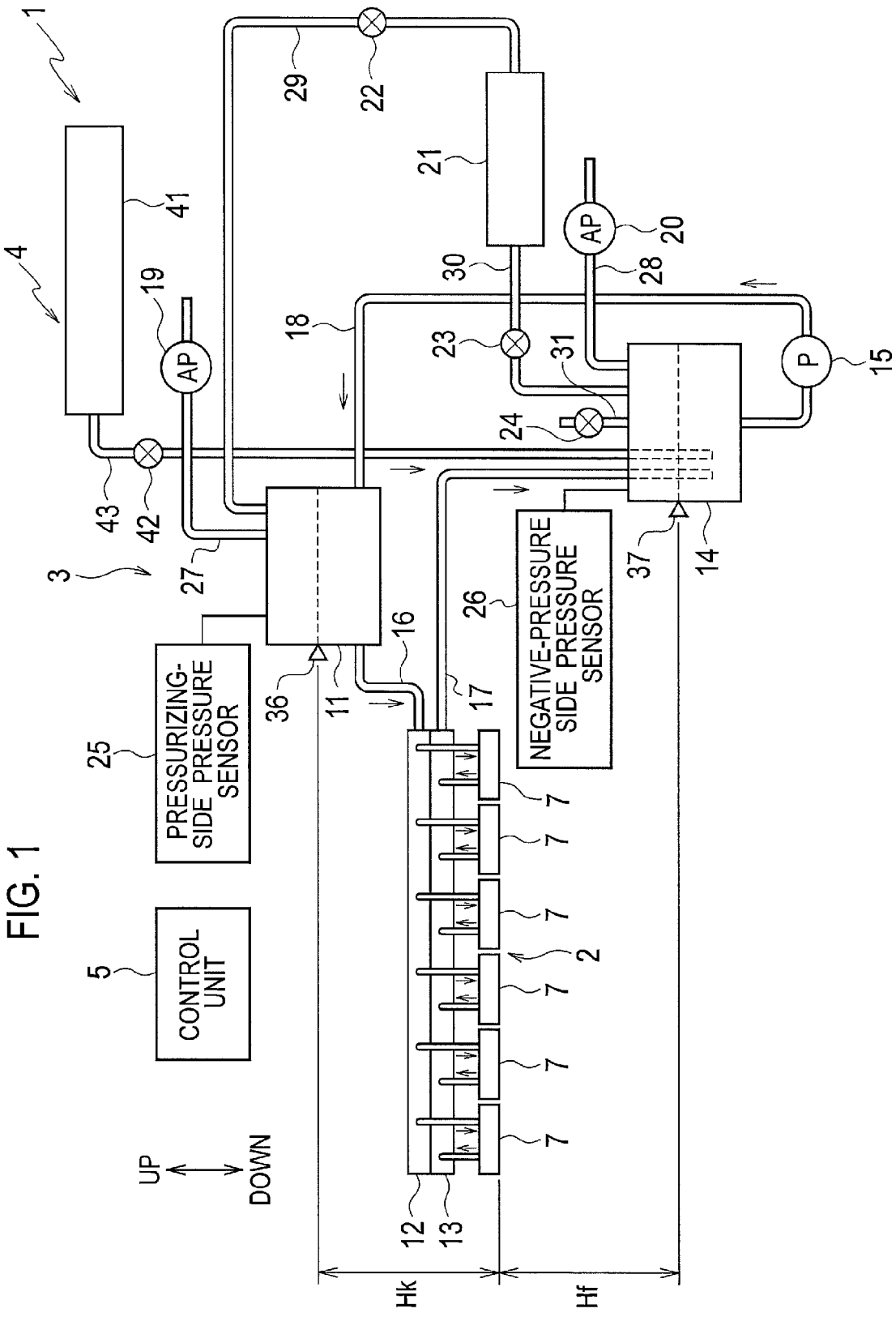
Primary Examiner — Stephen Meier
Assistant Examiner — John P Zimmermann
(74) *Attorney, Agent, or Firm* — Greenblum & Bernstein, P.L.C.

(57) **ABSTRACT**

A common air chamber is connected to an air layer of a pressurizing tank and to an air layer of a negative-pressure tank. A pressurizing-side communication valve opens/closes an air channel in an air conduit between the pressurizing tank and the common air chamber. A negative-pressure side communication valve opens/closes an air channel in an air conduit between the negative-pressure tank and the common air chamber. A negative-pressure tank atmospheric air opening valve switches the negative-pressure tank between a state shut off from the atmospheric air and a state open thereto. The pressurizing-side communication valve and the negative-pressure tank atmospheric air opening valve are of a normally-open type closed when electrified and open when not. The negative-pressure side communication valve is of a normally-closed type open when electrified and closed when not. While not electrified, a nozzle pressure of an inkjet head becomes a meniscus breakage pressure or less.

5 Claims, 4 Drawing Sheets

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P
15
37
14
26
16
36
11
17
25
PRESSURIZING-SIDE PRESSURE SENSOR
NEGATIVE-PRESSURE SIDE PRESSURE SENSOR
5
CONTROL UNIT
7
2
UP
DOWN
12
13
Hk
Hf

FIG. 1

FIG. 2

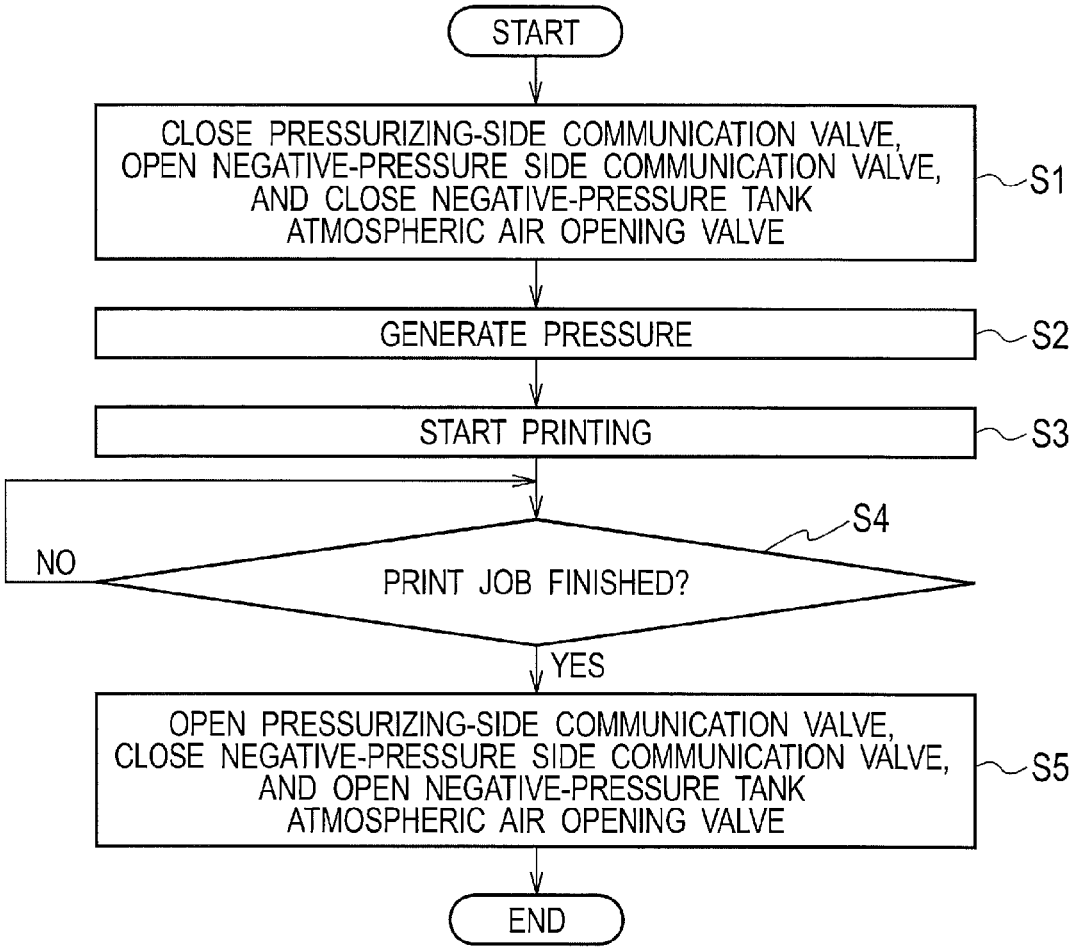
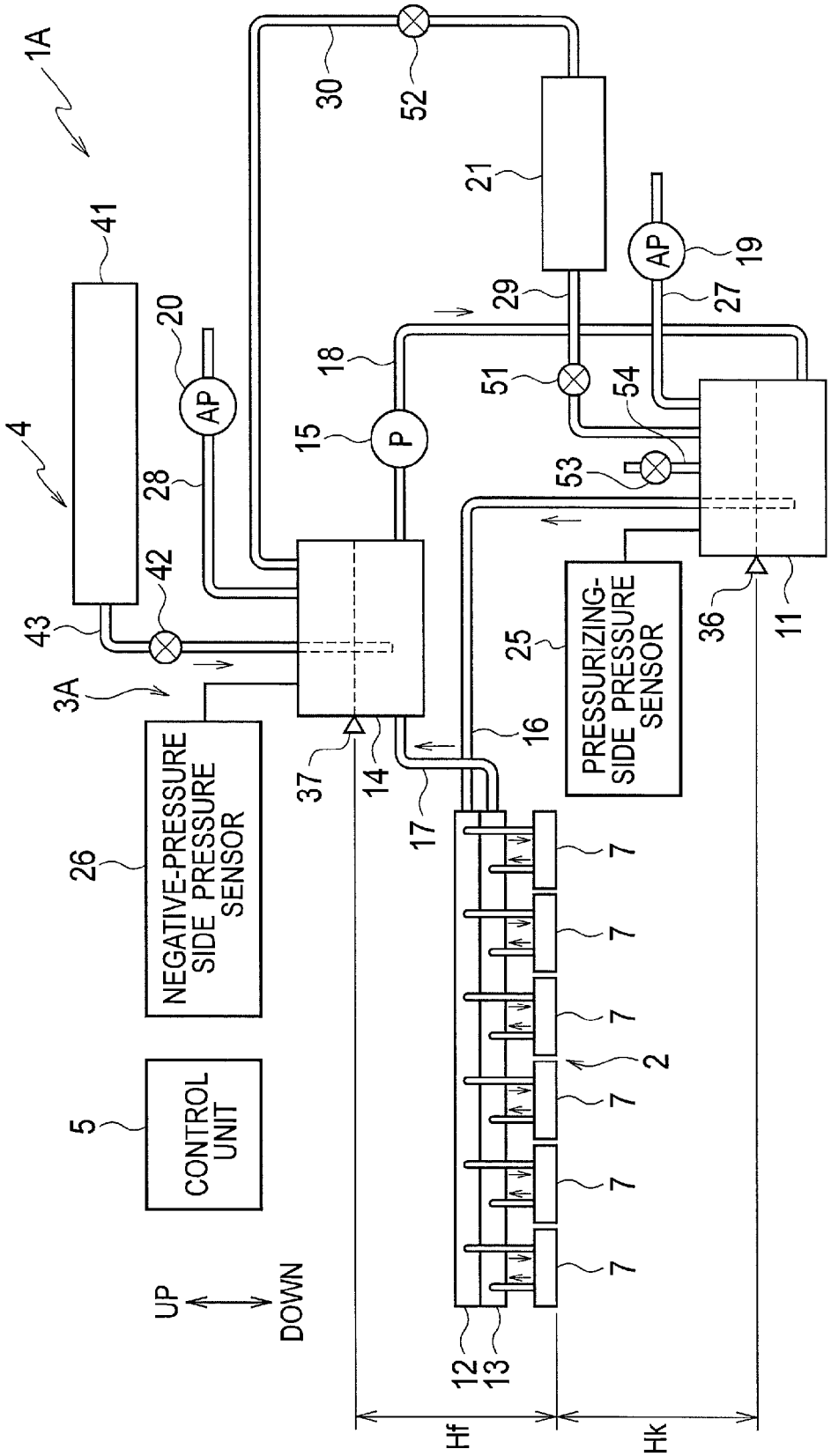


FIG. 3

		NEGATIVE-PRESSURE TANK LEVEL SENSOR	
		ON	OFF
PRESSURIZING TANK LEVEL SENSOR	ON	INK PUMP: OFF INK SUPPLY VALVE: CLOSE	INK PUMP: OFF INK SUPPLY VALVE: CLOSE
	OFF	INK PUMP: ON INK SUPPLY VALVE: CLOSE	INK PUMP: OFF INK SUPPLY VALVE: OPEN

FIG. 4


1A
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52
21
41
AP
19
29
27
20
AP
18
51
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4
15
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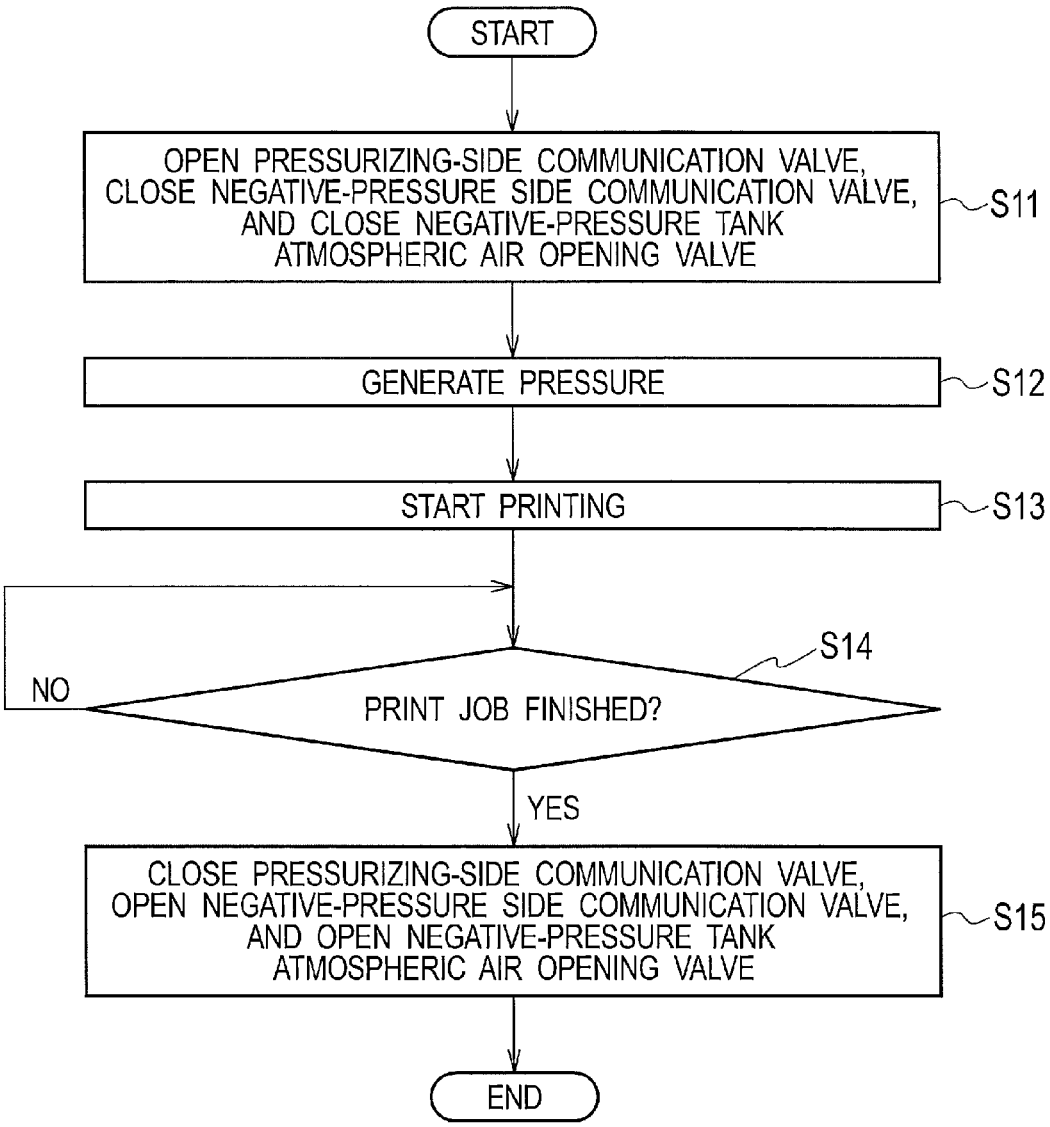
42
43
3A
25
PRESSURIZING-SIDE PRESSURE SENSOR
36
11
16
37
14
17
26
NEGATIVE-PRESSURE SIDE PRESSURE SENSOR
7
7
7
2
7
7
7
5
CONTROL UNIT
UP
DOWN
12
13
Hf
Hk

FIG. 5


START
OPEN PRESSURIZING-SIDE COMMUNICATION VALVE, CLOSE NEGATIVE-PRESSURE SIDE COMMUNICATION VALVE, AND CLOSE NEGATIVE-PRESSURE TANK ATMOSPHERIC AIR OPENING VALVE
S11
GENERATE PRESSURE
S12
START PRINTING
S13
S14
NO
PRINT JOB FINISHED?
YES
CLOSE PRESSURIZING-SIDE COMMUNICATION VALVE, OPEN NEGATIVE-PRESSURE SIDE COMMUNICATION VALVE, AND OPEN NEGATIVE-PRESSURE TANK ATMOSPHERIC AIR OPENING VALVE
S15
END

INKJET PRINTING APPARATUS

BACKGROUND

1. Technical Field

The present invention relates to an ink-circulation type inkjet printing apparatus.

2. Related Art

An ink-circulation type inkjet printing apparatus for printing in which ink is discharged from an inkjet head while ink is circulated is known.

The ink-circulation type inkjet printing apparatus includes the one in which a pressurizing tank is arranged at a high position and a negative-pressure tank is arranged at a lower position with respect to the inkjet head (see Patent Literature 1, for example).

In this type of inkjet printing apparatus, supply of ink from the pressurizing tank to the ink jet head and recovery of the ink from the inkjet head to the negative-pressure tank are performed by a water head pressure based on a positional relation between the pressurizing tank, the negative-pressure tank, and the inkjet head. To the pressurizing tank, the ink is fed from the negative-pressure tank by an ink pump.

In the type of inkjet printing apparatus as described above, in a standby state in which the ink circulation or printing is not performed, the negative-pressure tank is open to the atmospheric air. On the other hand, the pressurizing tank is brought into a sealed state by a valve in order to prevent the ink from flowing from the pressurizing tank to the negative-pressure tank.

In the inkjet head in which nozzles are arranged with high density in order to make printing with high resolution possible, an ink channel in the inkjet head is narrow, and channel resistance is large. When this type of the inkjet head is to be used, a required ink flowrate cannot be ensured only by the water head pressure by arrangement of the inkjet head, the pressurizing tank, and the negative-pressure tank as described above in some cases.

Thus, in order to ensure the required ink flowrate, an inkjet printing apparatus is known in which a positive pressure is applied to the pressurizing tank and a negative pressure is applied to the negative-pressure tank by using an air pump. In this type of the inkjet printing apparatus, the pressurizing tank and the negative-pressure tank are brought into the sealed state by valves, respectively, in the ink circulation, and a pressure is applied by an air pump. In the standby state, the pressurizing tank is brought into the sealed state, while the negative-pressure tank is brought into a state open to the atmospheric air as described above.

In this type of the inkjet printing apparatus, a normally-closed type electromagnetic valve is used which is open when being electrified and is closed when being non-electrified as a valve for switching the pressurizing tank between the state open to the atmospheric air and the sealed state. On the other hand, a normally-open type electromagnetic valve is used which is closed when being electrified and is open when being non-electrified as a valve for switching the negative-pressure tank between the state open to the atmospheric air and the sealed state. As a result, in a non-electrified state of each valve in the standby state or in a power-off state, the pressurizing tank can be brought into the sealed state, while the negative-pressure tank can be brought into the state open to the atmospheric air.

Here, the pressurizing tank is in the sealed state both during the ink circulation and standby, but when the ink circulation is finished and the state proceeds to the standby state, the valve of the pressurizing tank is temporarily opened so as to open the pressurizing tank to the atmospheric air and to release the pressure. That is because, if the negative-pressure tank is opened to the atmospheric air while the pressurizing tank is sealed and kept in a positive pressure, a pressure applied to the nozzle in the inkjet head rises and breaks meniscus of the ink, and there is a concern of ink leakage.

PRIOR ART DOCUMENT

Patent Literature

[Patent Literature 1] Japanese Patent Application Laid-Open Publication No. 2008-162262

SUMMARY

Problems to be Solved by the Invention

However, if power is shut off during the ink circulation for some reason, the sealed state of the pressurizing tank is maintained while control of temporarily opening the valve of the pressurizing tank cannot be executed. On the other hand, since the normally-open type valve of the negative-pressure tank is opened by shut-off of the power supply, the negative-pressure tank is changed from the sealed state to the atmospheric open state. As a result, since the negative-pressure tank is opened to the atmospheric air while the positive pressure of the pressurizing tank is kept, the pressure of the nozzle in the inkjet head rises, and there is a concern that meniscus of the ink is broken. If the meniscus is broken, there is a concern that ink leaks from the nozzle.

The present invention has been made in view of the above and has an object to provide an inkjet printing apparatus capable of suppression of breakage of meniscus of the ink in the nozzle.

Means for Solving the Problem

In order to achieve the above-described object, an aspect of an inkjet printing apparatus according to the present invention includes: an inkjet head having a nozzle discharging ink; a first tank arranged at a position higher than the inkjet head and storing the ink; a second tank arranged at a position lower than the inkjet head and storing the ink; a circulation path for circulating the ink among the first tank, the inkjet head, and the second tank; a positive-pressure applying portion for applying a positive pressure to one tank of the first and second tanks; a negative-pressure applying portion for applying a negative pressure to the other tank of the first and second tanks; a control unit for executing control of applying a predetermined positive pressure to one of the tanks by the positive-pressure applying portion, and executing control of applying a predetermined negative pressure to the other tank by the negative-pressure applying portion; a common air chamber connected to an air layer on ink in the first tank and an air layer on ink in the second tank through an air channel; a first valve which is closed when being electrified and is open when being non-electrified and opens/closes the air channel between the first tank and the common air chamber; a second valve which is open when being electrified and is closed when being non-electrified and opens/closes the air channel between the second tank and the common air chamber; and a third valve which is closed when being electrified and opened when being non-electrified and switches the second tank between a state shut off from the atmospheric air and a state

open to the atmospheric air, in which a nozzle pressure of the inkjet head becomes a meniscus breaking pressure or less when being non-electrified.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is an outline configuration view of an inkjet printing apparatus according to a first embodiment;

FIG. **2** is a flowchart for explaining an operation of the inkjet printing apparatus according to the first embodiment;

FIG. **3** is an explanatory view of control of an ink pump and an ink supply valve;

FIG. **4** is an outline configuration view of an inkjet printing apparatus according to a second embodiment; and

FIG. **5** is a flowchart for explaining an operation during printing of the inkjet printing apparatus according to the second embodiment.

DETAILED DESCRIPTION

Embodiments of the present invention will be described below with reference to the drawings. The same or equivalent reference numerals are given to the same or equivalent portions and constituent elements throughout the drawings. However, it should be noted that the drawings are schematic and different from real ones. Moreover, it is needless to say that portions with different relation between dimensions and ratios are included even among the drawings.

The embodiment illustrated below exemplifies an apparatus and the like for embodying a technical idea of the present invention, and the technical idea of the present invention does not limit a material, a shape, a structure, arrangement and the like of each component to those described below. The technical idea of the present invention can be changed in various ways in a claim.

First Embodiment

FIG. **1** is an outline configuration view of an inkjet printing apparatus according to a first embodiment of the present invention. An up-and-down direction in the description below refers to a vertical direction, and up and down in FIG. **1** is assumed to be an up-and-down direction.

As illustrated in FIG. **1**, the inkjet printing apparatus **1** according to the first embodiment includes an inkjet head **2**, an ink circulation unit **3**, an ink supply unit **4**, and a control unit **5**.

The inkjet head **2** discharges ink supplied by the ink circulation unit **3**. The inkjet head **2** is constituted by a plurality of head modules **7**.

The head module **7** has an ink chamber storing ink and a plurality of nozzles discharging the ink (none of them is shown). In the ink chamber, a piezo element (not shown) is arranged. The ink is discharged from the nozzle by driving of the piezo element.

The ink circulation unit **3** supplies the ink to the inkjet head **2** while circulating the ink. The ink circulation unit **3** includes a pressurizing tank **11**, an ink distributor **12**, an ink collector **13**, a negative-pressure tank **14**, an ink pump **15**, ink conduits **16** to **18**, a pressurizing-side air pump **19**, a negative-pressure side air pump **20**, a common air chamber **21**, a pressurizing-side communication valve **22**, a negative-pressure side communication valve **23**, a negative-pressure tank atmospheric air opening valve **24**, a pressurizing-side pressure sensor **25**, a negative-pressure side pressure sensor **26**, and air conduits **27** to **31**.

The pressurizing tank **11** stores the ink to be supplied to the inkjet head **2**. The ink in the pressurizing tank **11** is supplied to the inkjet head **2** through the ink conduit **16** and the ink distributor **12**. An air layer is formed on an ink level in the pressurizing tank **11**. The air layer in the pressurizing tank **11** is connected to the common air chamber **21** through the air conduit **29**. The pressurizing tank **11** is arranged at a position higher than (above) the inkjet head **2**. In the inkjet printing apparatus **1**, the pressurizing tank **11** corresponds to a first tank in the claim.

A pressurizing-tank level sensor **36** is provided in the pressurizing tank **11**. The pressurizing-tank level sensor **36** is to detect whether or not the ink level in the pressurizing tank **11** has reached a reference height. The pressurizing-tank level sensor **36** outputs a signal indicating "ON" when the ink level in the pressurizing tank **11** is at the reference height or more than the reference height. The pressurizing-tank level sensor **36** outputs a signal indicating "OFF" when the ink level in the pressurizing tank **11** is less than the reference height.

The ink distributor **12** distributes the ink supplied from the pressurizing tank **11** through the ink conduit **16** to each of the head modules **7** of the inkjet head **2**.

The ink collector **13** collects the ink not consumed in the inkjet head **2** from each of the head modules **7**. The ink collected by the ink collector **13** flows into the negative-pressure tank **14** through an ink conduit **17**.

The negative-pressure tank **14** receives the ink not consumed in the inkjet head **2** from the ink collector **13** and stores it. Moreover, the negative-pressure tank **14** stores the ink supplied from an ink cartridge **41** in the ink supply unit **4** which will be described later. An air layer is formed on the ink level in the negative-pressure tank **14**. The air layer in the negative-pressure tank **14** is connected to the common air chamber **21** through the air conduit **30**. The negative-pressure tank **14** is arranged at a position lower than (below) the inkjet head **2**. In the inkjet printing apparatus **1**, the negative-pressure tank **14** corresponds to a second tank in the claim.

A negative-pressure tank level sensor **37** is provided in the negative-pressure tank **14**. The negative-pressure tank level sensor **37** is to detect whether or not the ink level in the negative-pressure tank **14** has reached a reference height. The negative-pressure tank level sensor **37** outputs a signal indicating "ON" when the ink level in the negative-pressure tank **14** is at the reference height or more and outputs a signal indicating "OFF" when the ink level in the negative-pressure tank **14** is less than the reference height.

The ink pump **15** feeds the ink from the negative-pressure tank **14** to the pressurizing tank **11**. The ink pump **15** is provided in the middle of the ink conduit **18**.

The ink conduit **16** connects the pressurizing tank **11** and the ink distributor **12** to each other. In the ink conduit **16**, the ink flows from the pressurizing tank **11** toward the ink distributor **12**. The ink conduit **17** connects the ink collector **13** and the negative-pressure tank **14** to each other. In the ink conduit **17**, the ink flows from the ink collector **13** to the negative-pressure tank **14**. The ink conduit **18** connects the negative-pressure tank **14** and the pressurizing tank **11** to each other. In the ink conduit **18**, the ink flows from the negative-pressure tank **14** toward the pressurizing tank **11**. The ink conduits **16** to **18**, the ink distributor **12**, and the ink collector **13** constitute a circulation path through which the ink is circulated among the pressurizing tank **11**, the inkjet head **2**, and the negative-pressure tank **14**.

The pressurizing-side air pump **19** applies a positive pressure to the pressurizing tank **11** by feeding air to the pressurizing tank **11** through the air conduit **27**. The pressurizing-side air pump **19** is arranged in the middle of the air conduit

27. The pressurizing-side air pump **19** corresponds to a positive-pressure applying portion in the claim.

The negative-pressure side air pump **20** applies a negative pressure to the negative-pressure tank **14** by suctioning air from the negative-pressure tank **14** through the air conduit **28**. The negative-pressure side air pump **20** is arranged in the middle of the air conduit **28**. The negative-pressure side air pump **20** corresponds to a negative-pressure applying portion in the claim.

The common air chamber **21** is a space for releasing the pressure in the pressurizing tank **11** when the ink circulation ends. The common air chamber **21** is connected to the air layer in the pressurizing tank **11** through the air conduit **29** and is connected to the air layer in the negative-pressure tank **14** through the air conduit **30**.

The pressurizing-side communication valve **22** opens/closes an air channel in the air conduit **29**. When the pressurizing-side communication valve **22** is opened, the air layer in the pressurizing tank **11** is made to communicate with the common air chamber **21**. The pressurizing-side communication valve **22** is arranged in the middle of the air conduit **29**. The pressurizing-side communication valve **22** is constituted by a normally-open type electromagnetic valve which is closed when being electrified and is open when being non-electrified. In the inkjet printing apparatus **1**, the pressurizing-side communication valve **22** corresponds to a first valve in the claim.

The negative-pressure side communication valve **23** opens/closes an air channel in the air conduit **30**. When the negative-pressure side communication valve **23** is opened, the air layer in the negative-pressure tank **14** is made to communicate with the common air chamber **21**. The negative-pressure side communication valve **23** is arranged in the middle of the air conduit **30**. The negative-pressure side communication valve **23** is constituted by a normally-closed type electromagnetic valve which is open when being electrified and is closed when being non-electrified. In the inkjet printing apparatus **1**, the negative-pressure side communication valve **23** corresponds to a second valve in the claim.

The negative-pressure tank atmospheric air opening valve **24** switches the negative-pressure tank **14** between a state shut off from the atmospheric air and a state open to the atmospheric air. The negative-pressure tank atmospheric air opening valve **24** is arranged in the middle of the air conduit **31**. The negative-pressure tank atmospheric air opening valve **24** is a normally-open type electromagnetic valve. In the inkjet printing apparatus **1**, the negative-pressure tank atmospheric air opening valve **24** corresponds to a third valve in the claim.

The pressurizing-side pressure sensor **25** detects a pressure in the pressurizing tank **11**. The negative-pressure side pressure sensor **26** detects a pressure in the negative-pressure tank **14**.

The air conduit **27** forms a channel of air fed by the pressurizing-side air pump **19** to the pressurizing tank **11**. The air conduit **27** has one end connected to the air layer of the pressurizing tank **11** and the other end open to the atmospheric air.

The air conduit **28** forms a channel of air suctioned by the negative-pressure side air pump **20** from the negative-pressure tank **14**. The air conduit **28** has one end connected to the air layer of the negative-pressure tank **14** and the other end open to the atmospheric air.

The air conduit **29** forms an air channel between the pressurizing tank **11** and the common air chamber **21**. The air conduit **29** has one end connected to the air layer of the pressurizing tank **11** and the other end connected to the common air chamber **21**.

The air conduit **30** forms an air channel between the negative-pressure tank **14** and the common air chamber **21**. The air conduit **30** has one end connected to the air layer of the negative-pressure tank **14** and the other end connected to the common air chamber **21**.

The air conduit **31** forms a channel of air for opening the negative-pressure tank **14** to the atmospheric air. The air conduit **31** has one end connected to the air layer of the negative-pressure tank **14** and the other end open to the atmospheric air.

The ink supply unit **4** supplies the ink to the ink circulation unit **3**. The ink supply unit **4** includes the ink cartridge **41**, an ink supply valve **42**, and an ink conduit **43**.

The ink cartridge **41** accommodates ink used for printing by the inkjet head **2**. The ink in the ink cartridge **41** is supplied to the negative-pressure tank **14** of the ink circulation unit **3** through the ink conduit **43**.

The ink supply valve **42** opens/closes an ink channel in the ink conduit **43**. The ink supply valve **42** is constituted by a normally-closed type electromagnetic valve.

The ink conduit **43** connects the ink cartridge **41** and the negative-pressure tank **14** to each other. In ink supply, the ink flows from the ink cartridge **41** toward the negative-pressure tank **14** in the ink conduit **43**.

The control unit **5** controls an operation of each portion of the inkjet printing apparatus **1**. The control unit **5** includes a CPU, a RAM, a ROM, a hard disk and the like.

The control unit **5** closes the pressurizing-side communication valve **22**, opens the negative-pressure side communication valve **23**, and closes the negative-pressure tank atmospheric air opening valve **24** when printing is to be performed. Then, the control unit **5** applies the positive pressure to the pressurizing tank **11** by the pressurizing-side air pump **19** and applies the negative pressure to the negative-pressure tank **14** by the negative-pressure side air pump **20**. As a result, the ink circulation is performed in the ink circulation unit **3**. After the ink circulation is started, the control unit **5** executes control such that the ink is discharged from the inkjet head **2**. Here, since the negative-pressure side communication valve **23** is in an open state, the negative pressure is applied not only to the negative-pressure tank **14** but also to the common air chamber **21**.

When the ink circulation is to be ended, the control unit **5** reverses the open/closed state of the pressurizing-side communication valve **22**, the negative-pressure side communication valve **23**, and the negative-pressure tank atmospheric air opening valve **24** from the state during the ink circulation. That is, the control unit **5** opens the pressurizing-side communication valve **22**, closes the negative-pressure side communication valve **23**, and opens the negative-pressure tank atmospheric air opening valve **24**. As a result, the common air chamber **21** is shut off from the negative-pressure tank **14** so as to communicate with the pressurizing tank **11**. Since the pressurizing tank **11** is made to communicate with the common air chamber **21** in the negative pressure state, the pressure in the pressurizing tank **11** is lowered. Moreover, since the negative-pressure tank atmospheric air opening valve **24** is opened, the negative-pressure tank **14** is brought into the atmospheric air open state. As a result, the inkjet printing apparatus **1** is brought into the standby state.

Subsequently, an operation of the inkjet printing apparatus **1** will be described.

FIG. **2** is a flowchart for explaining the operation of the inkjet printing apparatus **1**. Processing in the flowchart in FIG. **2** is started when a print job is inputted into the inkjet printing apparatus **1**.

At Step S**1** in FIG. **2**, the control unit **5** closes the pressurizing-side communication valve **22**, opens the negative-pressure side communication valve **23**, and closes the negative-pressure tank atmospheric air opening valve **24**. As a result, the pressurizing tank **11** is shut off from the common air chamber **21**, and the negative-pressure tank **14** is made to communicate with the common air chamber **21**. The pressurizing tank **11** is singularly brought into a sealed state (state shut off from the atmospheric air). The negative-pressure tank **14** enters the sealed state together with the common air chamber **21**.

Subsequently, at Step S**2**, the control unit **5** generates a pressure. Specifically, the control unit **5** drives the pressurizing-side air pump **19** and feeds air to the air layer in the pressurizing tank **11**. As a result, the air layer in the pressurizing tank **11** is pressurized. When the positive pressure in the pressurizing tank **11** detected by the pressurizing-side pressure sensor **25** becomes a predetermined reference value, the control unit **5** stops the pressurizing-side air pump **19**. As a result, the pressurizing tank **11** enters a state in which the positive pressure at the reference value is applied.

Moreover, the control unit **5** drives the negative-pressure side air pump **20** and suctions the air from the air layer of the negative-pressure tank **14**. As a result, the pressures of the air layer in the negative-pressure tank **14** and the common air chamber **21** are reduced. When the negative pressure in the negative-pressure tank **14** detected by the negative-pressure side pressure sensor **26** becomes a predetermined reference value, the control unit **5** stops the negative-pressure side air pump **20**. As a result, the negative-pressure tank **14** and the common air chamber **21** enter a state in which the negative pressure at the reference value is applied.

When the positive pressure is applied to the pressurizing tank **11** and the negative pressure to the negative-pressure tank **14**, a flow of the ink is generated from the pressurizing tank **11** toward the negative-pressure tank **14** through the inkjet head **2**, and the ink circulation starts.

After that, at Step S**3**, the control unit **5** controls the inkjet head **2** on the basis of the print job and starts printing.

Here, when the printing is performed while the ink is circulated, the control unit **5** controls the ink pump **15** and the ink supply valve **42** in accordance with the states of the pressurizing-tank level sensor **36** and the negative-pressure tank level sensor **37**.

Specifically, as illustrated in FIG. **3**, in a state in which both the pressurizing-tank level sensor **36** and the negative-pressure tank level sensor **37** are ON, the control unit **5** turns off the ink pump **15** and closes the ink supply valve **42**. In a state in which the pressurizing-tank level sensor **36** is ON and the negative-pressure tank level sensor **37** is OFF, too, the control unit **5** turns off the ink pump **15** and closes the ink supply valve **42**.

In a state in which the pressurizing tank level sensor **36** is OFF and the negative-pressure tank level sensor **37** is ON, the control unit **5** turns on the ink pump **15** and closes the ink supply valve **42**.

In a state in which both the pressurizing-tank level sensor **36** and the negative-pressure tank level sensor **37** are OFF, the control unit **5** turns off the ink pump **15** and opens the ink supply valve **42**.

For example, if the ink circulation is started in the state in which both the pressurizing-tank level sensor **36** and the negative-pressure tank level sensor **37** are ON, the ink flows out of the pressurizing tank **11** to the inkjet head **2**, and the pressurizing-tank level sensor **36** is turned off soon. As a result, the control unit **5** drives the ink pump **15** and feeds the ink from the negative-pressure tank **14** to the pressurizing tank **11**. The level of the pressurizing tank **11** is raised by inflow of the ink from the negative-pressure tank **14**, and when the pressurizing-tank level sensor **36** is turned on, the control unit **5** stops the ink pump **15**.

As the printing proceeds, and the ink circulating in the inkjet head **2** and the ink circulation unit **3** decreases, the pressurizing-tank level sensor **36** and the negative-pressure tank level sensor **37** are both turned off soon. In this state, the control unit **5** opens the ink supply valve **42** and performs ink supply to the negative-pressure tank **14**.

When the negative-pressure tank level sensor **37** is turned on by the ink supply, the control unit **5** closes the ink supply valve **42** and ends the ink supply to the negative-pressure tank **14**. At this time, since the pressurizing-tank level sensor **36** is OFF and the negative-pressure tank level sensor **37** is ON, the control unit **5** drives the ink pump **15** and feeds the ink from the negative-pressure tank **14** to the pressurizing tank **11**. When the pressurizing-tank level sensor **36** is turned on, the control unit **5** stops the ink pump **15**.

By means of the control of the ink pump **15** and the ink supply valve **42** in accordance with the states of the pressurizing-tank level sensor **36** and the negative-pressure tank level sensor **37** as described above, printing is performed while the levels of the pressurizing tank **11** and the negative-pressure tank **14** are maintained in the vicinity of the reference heights.

Returning to FIG. **2**, subsequently to Step S**3**, at Step S**4**, the control unit **5** determines whether or not the print job has ended. If it is determined that the print job has not been ended (Step S**4**: NO), the control unit **5** repeats Step S**4**.

If it is determined that the print job has been ended (Step S**4**: YES), at Step S**5**, the control unit **5** opens the pressurizing-side communication valve **22**, closes the negative-pressure side communication valve **23**, and opens the negative-pressure tank atmospheric air opening valve **24**. As a result, the ink circulation ends, and the inkjet printing apparatus **1** enters the standby state.

As described above, when the ink circulation is finished, the negative-pressure side communication valve **23** is closed, and the negative-pressure tank atmospheric air opening valve **24** is opened, whereby the negative-pressure tank **14** is shut off from the common air chamber **21** and is open to the atmospheric air. Moreover, since the pressurizing-side communication valve **22** is opened, and the negative-pressure side communication valve **23** is closed, the pressurizing tank **11** is made to communicate with the common air chamber **21** and is brought into the sealed state together with the common air chamber **21**. Here, since the pressurizing tank **11** to which the positive pressure is applied and the common air chamber **21** to which the negative pressure is applied during the ink circulation are made to communicate with each other, the pressure of the pressurizing tank **11** is lowered. As will be described later, it is configured that the magnitude of the nozzle pressure of the inkjet head **2** becomes a meniscus breakage pressure or less at this time. Therefore, the ink circulation state can proceed to the standby state while breakage of the meniscus of the ink in the nozzle is suppressed.

Here, if the power supply of the inkjet printing apparatus **1** is shut off during the ink circulation, the pressurizing-side communication valve **22**, the negative-pressure side communication valve **23**, and the negative-pressure tank atmospheric air opening valve **24** are brought into the non-electrified state. Thus, the pressurizing-side communication valve **22** and the negative-pressure tank atmospheric air opening valve **24** of

the normally-open type are opened, respectively, and the negative-pressure side communication valve **23** of the normally-closed type is closed. That is, even if the power supply is shut off during the ink circulation and opening/closing control of the pressurizing-side communication valve **22**, the negative-pressure side communication valve **23**, and the negative-pressure tank atmospheric air opening valve **24** is impossible, these valves are brought into the open/closed state similar to the case in which the ink circulation is finished by the above-described control of the control unit **5**.

Therefore, even if the power supply is shut off during the ink circulation, the inkjet printing apparatus **1** can proceed to the standby state while breakage of the meniscus of the ink in the nozzle of the inkjet head **2** is suppressed. If meniscus breakage occurs, ink leaks from the nozzle, but this can be avoided.

Subsequently, a condition that the meniscus of the ink in the nozzle is not broken when the pressurizing-side communication valve **22** and the negative-pressure tank atmospheric air opening valve **24** are opened, respectively, and the negative-pressure side communication valve **23** is closed from the ink circulation state will be described. The pressure is assumed to be a gauge pressure.

A nozzle pressure P_n is expressed by Formula 1 below.

$$P_n = \frac{1}{2}\{(P_k + P_{Hk}) + (P_f + P_{Hf})\} \quad \text{[Formula 1]}$$

Here, P_k is a pressure of the pressurizing tank **11**. P_f is a pressure of the negative-pressure tank **14**. P_{HK} is a water head pressure based on a height difference (water head difference) H_k between a level of the pressurizing tank **11** and the nozzle surface of the inkjet head **2**. P_{Hf} is a water head pressure based on a height difference (water head difference) H_f between a level of the nozzle surface of the inkjet head **2** and the liquid level of the negative-pressure tank **14**.

If the nozzle pressure P_n is at a meniscus breakage pressure P_{n_max} or less, the meniscus of the ink in the nozzle is not broken. That is, if Formula 2 below is satisfied, the meniscus of the ink in the nozzle is not broken.

$$P_{n\_max} \geq \frac{1}{2}|(P_k + P_{Hk}) + (P_f + P_{Hf})| \quad \text{[Formula 2]}$$

The meniscus breakage pressure P_{n_max} is a value determined in accordance with the nozzle diameter and a surface tension of the ink.

As described above, in the inkjet printing apparatus **1**, the pressurizing-side communication valve **22** is opened and the negative-pressure side communication valve **23** is closed, and the common air chamber **21** is shut off from the negative-pressure tank **14** and the common air chamber **21** is made to communicate with the pressurizing tank **11** during the ink circulation. Assuming that pressure of the pressurizing tank **11** and the common air chamber **21** after the communication between the pressurizing tank **11** and the common air chamber **21** is P_x, Formula 3 below is established by Boyle's Law.

$$P_k \times V_k + P_f \times V_{com} = P_x \times (V_k + V_{com}) \quad \text{[Formula 3]}$$

Here, V_k is an air amount of a pressurizing system. V_{com} is an air amount of a common air chamber system.

The air amount V_k of the pressurizing system is an air amount of a portion made to communicate with the pressurizing tank **11** during the ink circulation and to which the positive pressure is applied together with the pressurizing tank **11**. The air amount V_k of the pressurizing system is expressed by Formula 4 below.

$$V_k = V_{kt} + V_{kr1} + V_{kr2} \quad \text{[Formula 4]}$$

Here, V_{kt} is a capacity of the air layer in the pressurizing tank **11**. That is, V_{kt} corresponds to a volume of a space above the reference height of the level in the pressurizing tank **11**. V_{kr1} is a capacity of a portion of the air conduit **27** between the pressurizing tank **11** and the pressurizing-side air pump **19**. V_{kr2} is a capacity of a portion of the air conduit **29** between the pressurizing tank **11** and the pressurizing-side communication valve **22**.

The air amount V_{com} of the common air chamber system is an air amount of a portion made to communicate with the pressurizing tank **11** after the ink circulation is finished in a portion made to communicate with the negative-pressure tank **14** during the ink circulation and to which the negative pressure is applied together with the negative-pressure tank **14**. The air amount V_{com} of the common air chamber system is expressed by Formula 5 below.

$$V_{com} = V_{ct} + V_{cr1} + V_{cr2} \quad \text{[Formula 5]}$$

Here, V_{ct} is a capacity of the common air chamber **21**. V_{cr1} is a capacity of a portion in the air conduit **30** between the common air chamber **21** and the negative-pressure side communication valve **23**. V_{cr2} is a capacity of a portion in the air conduit **29** between the common air chamber **21** and the pressurizing-side communication valve **22**.

From the Formula 3, the pressure P_x of the pressurizing tank **11** after being made to communicate with the common air chamber **21** is expressed by the Formula 6 below.

$$P_x = \frac{P_k \times V_k + P_f \times V_{com}}{V_k + V_{com}} \quad \text{[Formula 6]}$$

When the pressurizing tank **11** and the common air chamber **21** are made to communicate with each other at the end of the ink circulation, the negative-pressure tank atmospheric air opening valve **24** is opened, whereby the negative-pressure tank **14** is opened to the atmospheric air. As a result, $P_f=0$ is obtained.

Therefore, if Formula 7 below obtained by substituting $P_k=P_x$, $P_f=0$ in the above-described Formula 2 is satisfied, when the ink circulation state proceeds to the standby state, meniscus of the ink in the nozzle is not broken. The right side in Formula 7 is a magnitude of the nozzle pressure according to the pressure P_x after communication between the pressurizing tank **11** and the common air chamber **21**.

$$P_{n\_max} \geq \left|\frac{P_x + P_{Hk} + P_{Hf}}{2}\right| \quad \text{[Formula 7]}$$

By substituting Formula 6 in Formula 7 and deforming it, Formula 8 below can be obtained. The condition that meniscus of the ink in the nozzle is not broken when the ink circulation state proceeds to the standby state is that Formula 8 is satisfied.

$$2P_{n\_max} \geq \left|\frac{P_k \times V_k + P_f \times V_{com}}{V_k + V_{com}} + P_{Hk} + P_{Hf}\right| \quad \text{[Formula 8]}$$

The inkjet printing apparatus **1** is designed such that the air layer of the pressurizing tank **11** and the common air chamber **21** have such capacities that Formula 8 is satisfied. As a result, the magnitude of the nozzle pressure of the inkjet head **2** when the ink circulation state proceeds to the standby state becomes the meniscus breakage pressure or less.

As described above, in the inkjet printing apparatus **1**, when the power supply is shut off during the ink circulation, the normally-open type pressurizing-side communication valve **22** and the negative-pressure tank atmospheric air opening valve **24** are opened, respectively, and the normally-closed type negative-pressure side communication valve **23** is closed. As a result, the negative-pressure tank **14** is shut off from the common air chamber **21** and is opened to the atmospheric air. Moreover, the pressurizing tank **11** is made to communicate with the common air chamber **21**. Since the pressurizing tank **11** to which the positive pressure is applied during the ink circulation is made to communicate with the common air chamber **21** to which the negative pressure is applied, the pressure of the pressurizing tank **11** is lowered. Since the air layer of the pressurizing tank **11** and the common air chamber **21** have such capacities that the magnitude of the nozzle pressure according to the pressure P_x after communication between the pressurizing tank **11** and the common air chamber **21** becomes the meniscus breakage pressure or less, the nozzle pressure after shut-off of the power supply (when being non-electrified) can be suppressed to the meniscus breakage pressure or less. Thus, breakage of meniscus of the ink in the nozzle can be suppressed. As a result, ink leakage from the nozzle can be suppressed.

Second Embodiment

FIG. **4** is an outline configuration view of an inkjet printing apparatus according to a second embodiment.

As illustrated in FIG. **4**, the inkjet printing apparatus **1**A according to the second embodiment has a constitution in which the ink circulation unit **3** is replaced by an ink circulation unit **3**A with respect to the inkjet printing apparatus **1** in the first embodiment as illustrated in FIG. **1**.

The ink circulation unit **3**A has arrangement of the pressurizing tank **11** and the negative-pressure tank **14** changed with respect to the ink circulation portion **3** in FIG. **1**. Moreover, the ink circulation unit **3**A is, with respect to the ink circulation portion **3**, a constitution in which the pressurizing-side communication valve **22** and the negative-pressure side communication valve **23** are replaced by the pressurizing-side communication valve **51** and the negative-pressure side communication valve **52**, respectively, the negative-pressure tank atmospheric air opening valve **24** and the air conduit **31** are omitted, and a pressurizing tank atmospheric air opening valve **53** and an air conduit **54** are added.

In the ink circulation unit **3**A, the pressurizing tank **11** is arranged at a position lower than (below) the inkjet head **2**. The negative-pressure tank **14** is arranged at a position higher than (above) the inkjet head **2**. In the inkjet printing apparatus **1**A, the negative-pressure tank **14** corresponds to the first tank in the claim, and the pressurizing tank **11** corresponds to the second tank in the claim.

The pressurizing-side communication valve **51** is unlike the pressurizing-side communication valve **22** in the ink circulation unit **3** in FIG. **1** but is constituted by a normally-closed type electromagnetic valve. In the inkjet printing apparatus **1**A, the pressurizing-side communication valve **51** corresponds to the second valve in the claim.

The negative-pressure side communication valve **52** is unlike the negative-pressure side communication valve **23** in the ink circulation unit **3** in FIG. **1** but is constituted by a normally-open type electromagnetic valve. In the inkjet printing apparatus **1**A, the negative-pressure side communication valve **52** corresponds to the first valve in the claim.

The pressurizing-tank atmospheric air opening valve **53** switches the pressurizing tank **11** between a state shut off from the atmospheric air and a state open to the atmospheric air. The pressurizing-tank atmospheric air opening valve **53** is arranged in the middle of the air conduit **54**. The pressurizing-tank atmospheric air opening valve **53** is constituted by a normally-open type electromagnetic valve. In the inkjet printing apparatus **1**A, the pressurizing-tank atmospheric air opening valve **53** corresponds to the third valve in the claim.

The air conduit **54** forms an air channel for opening the pressurizing tank **11** to the atmospheric air. The air conduit **54** has one end connected to the air layer in the pressurizing tank **11** and the other end open to the atmospheric air.

Subsequently, an operation of the inkjet printing apparatus **1**A will be described.

FIG. **5** is a flowchart for explaining the operation of the inkjet printing apparatus **1**A. Processing in the flowchart in FIG. **5** is started when a print job is inputted into the inkjet printing apparatus **1**A.

At Step S**11** in FIG. **5**, the control unit **5** opens the pressurizing-side communication valve **51**, closes the negative-pressure side communication valve **52**, and closes the pressurizing-tank atmospheric air opening valve **53**. As a result, the negative-pressure tank **14** is shut off from the common air chamber **21**, and the pressurizing tank **11** is made to communicate with the common air chamber **21**. The negative-pressure tank **14** is singularly brought into a sealed state. The pressurizing tank **11** enters the sealed state together with the common air chamber **21**.

Subsequently, at Step S**12**, the control unit **5** generates a pressure. Processing at Step S**12** is similar to the above-described processing at Step S**2** in FIG. **2**. By means of this processing, the negative pressure at a reference value is applied to the negative-pressure tank **14**, and the positive pressure at a reference value is applied to the pressurizing tank **11** and the common air chamber **21**. As a result, a flow of the ink from the pressurizing tank **11** toward the negative-pressure tank **14** through the inkjet head **2** is generated, and the ink circulation is started.

Processing at Steps S**13** and S**14** subsequent to Step S**12** is similar to the above-described processing at Steps S**3** and S**4** in FIG. **2**. Moreover, control of the ink pump **15** and the ink supply valve **42** illustrated in FIG. **3** is also executed similarly.

If it is determined at Step S**14** that the print job has been finished (Step S**14**: YES), at Step S**15**, the control unit **5** closes the pressurizing-side communication valve **51**, opens the negative-pressure side communication valve **52**, and opens the pressurizing-tank atmospheric air opening valve **53**. As a result, the ink circulation is finished, and the inkjet printing apparatus **1** enters the standby state.

As described above, when the ink circulation is finished, the pressurizing-side communication valve **51** is closed, and the pressurizing tank atmospheric air opening valve **53** is opened, whereby the pressurizing tank **11** is shut off from the common air chamber **21** and is opened to the atmospheric air. Moreover, the negative-pressure side communication valve **52** is opened, and the pressurizing-side communication valve **51** is closed, whereby the negative-pressure tank **14** is made to communicate with the common air chamber **21** and is brought into the sealed state together with the common air chamber **21**. Here, since the negative-pressure tank **14** to which the negative pressure is applied and the common air chamber **21** to which the positive pressure is applied during the ink circu-

lation are made to communicate with each other, the pressure of the negative-pressure tank **14** rises. As will be described later, it is configured that the magnitude of the nozzle pressure of the inkjet head **2** becomes the meniscus breakage pressure or less at this time. Therefore, the ink circulation state can proceed to the standby state while breakage of meniscus of the ink in the nozzle is suppressed.

Here, if the power supply of the inkjet printing apparatus **1**A is shut off during the ink circulation, the pressurizing-side communication valve **51**, the negative-pressure side communication valve **52**, and the pressurizing-tank atmospheric air opening valve **53** are brought into the non-electrified state. Thus, the negative-pressure side communication valve **52** and the pressurizing-tank atmospheric air opening valve **53** of the normally-open type are opened, respectively, and the pressurizing-side communication valve **51** of the normally-closed type is closed. That is, even if the power supply is shut off during the ink circulation and opening/closing control of the pressurizing-side communication valve **51**, the negative-pressure side communication valve **52**, and the pressurizing-tank atmospheric air opening valve **53** is impossible, these valves are brought into the open/closed state similar to the case in which the ink circulation is finished by the above-described control of the control unit **5**.

Therefore, even if the power supply is shut off during the ink circulation, the inkjet printing apparatus **1**A can proceed to the standby state while breakage of the meniscus of the ink in the nozzle of the inkjet head **2** is suppressed. If meniscus breakage occurs, air suctioning from the nozzle occurs, but this can be avoided.

In the inkjet printing apparatus **1**A, a condition that meniscus of the ink in the nozzle is not broken when the ink circulation state proceeds to the standby state is satisfaction of Formula 9 below. The Formula 9 is derived by the same method as the above-described Formula 8.

$$2P_{n\_max} \geq \left| \frac{P_f \times V_f + P_k \times V_{com}}{V_f + V_{com}} + P_{Hk} + P_{Hf} \right| \quad \text{[Formula 9]}$$

Here, V_f is an air amount of a negative-pressure system. The air amount V_f of the negative-pressure system is an air amount of a portion made to communicate with the negative-pressure tank **14** during the ink circulation and to which the negative pressure is applied together with the negative-pressure tank **14**. The air amount V_f of the negative-pressure system is expressed by Formula 10 below.

$$V_f = V_{ft} + V_{fr1} + V_{fr2} \quad \text{[Formula 10]}$$

Here, V_{ft} is a capacity of the air layer in the negative-pressure tank **14**. That is, V_{ft} corresponds to a volume of a space above the reference height of the level in the negative-pressure tank **14**. V_{fr1} is a capacity of a portion of the air conduit **28** between the negative-pressure tank **14** and the negative-pressure side air pump **20**. V_{fr2} is a capacity of a portion of the air conduit **30** between the negative-pressure tank **14** and the negative-pressure side communication valve **52**.

The air amount V_{com} of a common air chamber system in the inkjet printing apparatus **1**A is an air amount of a portion made to communicate with the negative-pressure tank **14** after the ink circulation is finished in a portion made to communicate with the pressurizing tank **11** during the ink circulation and to which the positive pressure is applied together with the pressurizing tank **11**.

The air amount V_{com} of the common air chamber system is expressed by the above-described Formula 5, and in the inkjet printing apparatus **1**A, V_{cr1} in Formula 5 is a capacity of a portion in the air conduit **30** between the common air chamber **21** and the negative-pressure side communication valve **52**. V_{cr2} is a capacity of a portion in the air conduit **29** between the common air chamber **21** and the pressurizing-side communication valve **51**.

The inkjet printing apparatus **1**A is designed such that the air layer of the negative-pressure tank **14** and the common air chamber **21** have such capacities that Formula 9 is satisfied. As a result, the magnitude of the nozzle pressure of the inkjet head **2** when the ink circulation state proceeds to the standby state becomes the meniscus breakage pressure or less.

In the inkjet printing apparatus **1**A as above, too, the nozzle pressure after the power supply shut-off can be kept to the meniscus breakage pressure or less. Thus, breakage of meniscus of the ink in the nozzle can be suppressed. As a result, air suctioning from the nozzle can be suppressed.

While embodiments of the present invention have been described hereinabove, these embodiments are merely illustration described for the purpose of facilitating the understanding of the present invention, and the present invention is not limited to the embodiments. The technical scope of the present invention is not limited to the specific technical matters disclosed in the embodiments but includes various modifications, changes, alternative techniques, and the like which can readily be conceived therefrom.

The entire content of Japanese Patent Application No. 2014-155064 (filed on Jul. 30, 2014) is incorporated herein by reference.

INDUSTRIAL APPLICABILITY

According to the features of the inkjet printing apparatus according to the present invention, since the nozzle pressure of the inkjet head becomes the meniscus breakage pressure or less in the non-electrified state, even if the power supply is shut off during the ink circulation, the nozzle pressure after the shut-off of the power supply can be kept to the meniscus breakage pressure or less. Therefore, breakage of meniscus of the ink in the nozzle can be suppressed.

REFERENCE SIGNS LIST

1, **1**A inkjet printing apparatus
2 inkjet head
3, **3**A ink circulation unit
4 ink supply unit
5 control unit
11 pressurizing tank
12 ink distributor
13 ink collector
14 negative-pressure tank
15 ink pump
16 to **18**, **43** ink conduit
19 pressurizing-side air pump
20 negative-pressure side air pump
21 common air chamber
22, **51** pressurizing-side communication valve
23, **52** negative-pressure side communication valve
24 negative-pressure tank atmospheric air opening valve
25 pressurizing-side pressure sensor
26 negative-pressure side pressure sensor
27 to **31** air conduit
41 ink cartridge
42 ink supply valve
53 pressurizing-tank atmospheric air opening valve

What is claimed is:

1. An inkjet printing apparatus comprising:

an inkjet head having a nozzle discharging ink;

a first tank arranged at a position higher than the inkjet head and storing the ink;

a second tank arranged at a position lower than the inkjet head and storing the ink;

a circulation path for circulating the ink among the first tank, the inkjet head, and the second tank;

a positive-pressure applying portion for applying a positive pressure to one tank of the first and second tanks;

a negative-pressure applying portion for applying a negative pressure to the other tank of the first and second tanks;

a control unit for

executing control of applying a predetermined positive pressure to one of the tanks by the positive-pressure applying portion, and

executing control of applying a predetermined negative pressure to the other tank by the negative-pressure applying portion;

a common air chamber connected to an air layer on ink in the first tank and an air layer on ink in the second tank through an air channel;

a first valve which is closed when being electrified and is open when being non-electrified and opens/closes the air channel between the first tank and the common air chamber;

a second valve which is open when being electrified and is closed when being non-electrified and opens/closes the air channel between the second tank and the common air chamber; and

a third valve which is closed when being electrified and opened when being non-electrified and switches the second tank between a state shut off from the atmospheric air and a state open to the atmospheric air, wherein

a nozzle pressure of the inkjet head becomes a meniscus breaking pressure or less when being non-electrified, and

the air channel connecting the common air chamber to the air layer in the first tank and the air layer in the second tank is different than the circulating path that circulates the ink between the first tank, the inkjet head and the second tank.

2. The inkjet printing apparatus according to claim 1, wherein

the air channel is configured to allow air flow between the air layer in the first tank, the common air chamber, and the air layer in the second tank.

3. The inkjet printing apparatus according to claim 1, wherein

the positive-pressure applying portion applies a positive pressure to the first tank through a first air conduit,

the negative-pressure applying portion applies a negative pressure to the second tank through a second air conduit,

the first air conduit is connected to the air layer of the first tank, and

the second air conduit is connected to the air layer of the second tank.

4. The inkjet printing apparatus according to claim 1, wherein

the circulation path includes a first ink conduit that connects the ink in the first tank to the inkjet head, a second ink conduit that connects the inkjet head to the ink in the second tank, and a third ink conduit that connects the ink in the second tank to the ink in the first tank.

5. The inkjet printing apparatus according to claim 1, wherein

the inkjet head includes an ink distributor that receives ink from the first tank and an ink collector that collects ink not consumed in the inkjet head, and

the circulation path includes a first ink conduit that is configured to supply the ink in the first tank to the ink distributor, a second ink conduit that is configured to flow ink collected in the ink collector to the second tank, and a third ink conduit that connects the ink in the second tank to the ink in the first tank.

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